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Case Report

Interoperability Between Smart Building and Mobile Robots: Application to the Path Finding Problem

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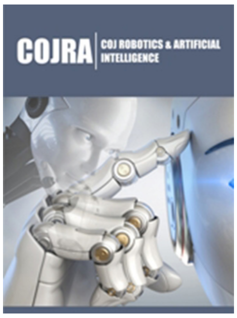

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Abstract

Allowing autonomous robot to move inside of a built environment requires a set of sensors and software components. Thus, it will perceive its direct environment and act accordingly. This use case is the subject of numerous research studies in the field of path finding. Some issues are linked to the needs of interoperability between sensors to build a relevant movement strategy. Beyond the aspect of immediate mobility, the question to be addressed is: how to optimize the movement of the robot by limiting the time and processing constraints linked to the discovery of its environment? In this article, we propose an interoperability approach associating the robot and its intelligent built environment. The goal of this collaboration is to optimize all decisions that the robot must make by acquiring data perceived by the building (its topology, the physical constraints to be processed and the calculation of the best path).

Keywords: Cyber-physical systems; Cooperative; Environment; Interoperability; Ontologies; Robots

Introduction

The conception of an optimal pathway for autonomous mobile robots is an issue much research on robotics are focused on [1,2]. This issue is usually addressed in two fronts. For one side, robots deal with short-distance issues such as obstacles. Sets of sensors assist robots to avoid these obstacles. Even though, the scope of these instruments is limited [3]. On the other side, long distance displacements require planning. The construction of pathways depends on environment conception of the space. Wise solutions like MAKLINK graphs are proposed [4,5] to define a free space model for robots. The MAKLINK model generates a space over fixed obstacles where a robot can move freely. Dijkstra algorithm is applied [6] to determine the shortest pathway between two nodes. In terms of physical dimension, Dijkstra algorithm considers distance between intermediate nodes as a choice factor. An innovating system inspired by colonies of insects, named Ant Colony System (ACS) is used [6,7] to optimize pathways, considering previous experience. However, the whole described solutions concentrate efforts to discover optimal pathways on fixed pre-conceived spaces.

Case Presentation

In this paper we present a collaborative environment system named O4IRB. The objective of O4IRB is to cooperate robots, through reorganizing dynamically building spaces. The aim of this reciprocal cooperation is to construct an optimal pathway solution to conduct robots to their desired or most advantageous destinies. While, building profits of a harmonic distribution of individuals to avoid overpopulation of its spaces. OI4IRB cyber-physical system is composed of heterogeneous Internet of Things (IoT) devices. The ontologies used in OI4RB are Semantic Sensor Networks (SSN), Event Ontology and Building Ontology Topology (BOT) [8]. These three ontologies are combined to integrate heterogeneous sources such as IoT.

These devices equipped the robots as well as the building, making it smart. In our experiment the smart building know its topology, has services to calculate a pathway from a source to a target space, as services to adapt the pathway to the profile of the robots and constraints on space connection (doors, elevator, stair). To allow the interoperability between these devices we built a specific ontology in Shroin(D) description logic. This formal model makes causal reasoning rules possible to improve robot's movement strategy and acts on building actuators. These lasts change the state of the building connections to make easier moving robots.

Via this system, robots share identity and position data. They also provide their intended destinies. This data is stored and analyzed in the ontology. SPARQL queries are made to determine optimal paths for robots. The building articulates controlled doors to provide an advantageous pathway. While robots progress on their displacements O4IRB reorganize constantly the spaces connection until robots reach their destination. Contrary to Dijkstra algorithm, O4IRB does not create a shortest pathway between two spaces. Instead it considers the population of spaces to reduce collision between individuals and takes care of the structural constraints of the building. The carried-out experimentation is centered in a scale model. This last is a floor of a building. It comprehends ten rooms, six of them have doors controlled by servo motors. In addition, Radio Frequency Identifier (RFID) readers are in each room. Robots use RFID tags containing information described before. Five bug autonomous-displacement robots are identified in the interior of the building model. Two of them stand out labeled RED and BLUE. The approach of these two labeled robots is to find each other. The approach of the building is to gather them in an empty room, to bypass a possible bottleneck.

The performance of O4IRB follows a cycle. The system initiates with the lecture of robot tags. The collected data is stored and analyzed by the system. Then it changes the states of doors to creates a common space to conduct robots. Constantly O4IRB tracks RED and BLUE robots. As soon as they progress on their displacements trough the created pathway, the system creates a new configuration of spaces. Once the goal is accomplished the system keeps both robots isolated.

Discussion

Cyber-physical systems play the role of an interface between the physical real world and the cyber world where information is processed, stored, and exploited [9]. These are usually large wireless network systems (WSN). This last provides a vast source of data related to the environmental conditions. Generally, they are employed to monitor weather conditions. Ontologies are description of concepts and the relation between them [10]. Some other research use ontologies as Building Energy Management Systems (BEMS) [11]. The association of CPS and ontologies is well known. In terms of pathways ontologies are used to describe building environments to assist sensors like cameras [12]. Building Topology Ontology (BOT) [8] provides a simple description of buildings and has been used to complement sensors scope. It is imperative to determine a minimum distance between origin and destiny. Algorithms like Dijkstra or MAKLINK determine minimum distances between spatial point by identifying intermediate nodes distances. However, they require a previous sketch of position and distance between objects [6]. This dependency makes the algorithm useless on dynamic environments. ACS algorithm works on multiple trajectories. In principle ACS is used to determine the quickest pathway, turning out historical data.

This paper presented a cooperative system between robots and smart building. The system named O4IRB mixed data from robots and building to make reasoning and adapt the building configuration according to the robots moving. The system O4IRB works on real time and provides optimal pathways for robots. The novelty of our approach is to reduce processing load and hardware of robots by adding a global perception and reasoning on mobility at the building level. Thanks to the ontology features, our system is extensible and, for example, will be improved by new sensors (smart cameras) both on the robots and the building.

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